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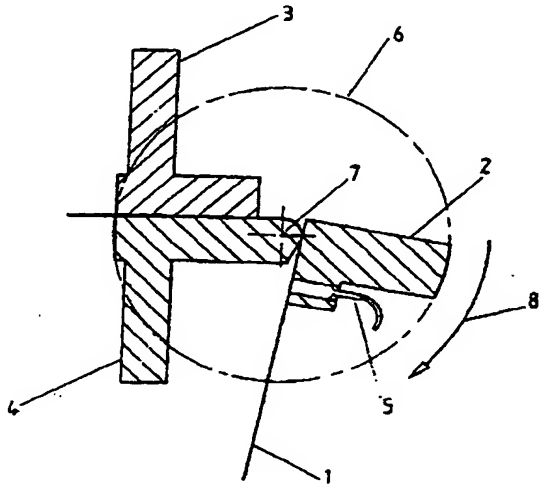
(54) Sheet metal folder, controller and method

(57) A sheet metal folder includes a movable fold bar, an actuator to move the movable fold bar and a sheet position monitor which monitors the position of the folded portion of a sheet being folded. During folding, a controller moves the fold bar to a first fold position and retreats the fold bar to a position in which the sheet is no longer contacted by the fold bar. The current position of the sheet is then registered. A second fold position is calculated using the difference between the first fold position of the fold bar and the registered position. The fold bar is then moved to the second fold position. The sheet position monitor may involve a detector detecting the presence of a folded part of the sheet against the fold bar, with the current position of the sheet after the fold bar is retreated being registered by registering the position of the fold bar immediately the sheet no longer resides against the fold bar.

FIG. 2



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Description

BACKGROUND TO THE INVENTION

1) Field of the Invention

[0001] This invention relates to sheet metal folders, and in particular to improved control system for controlling movement of the fold bar of a sheet metal tangent folder or bender to ensure an accurate bend angle.

ii) Summary of the Prior Art

[0002] For some sheet metal forming operations a tangent folder is employed. In a tangent folder a moving fold bar has a surface which faces the centre of curvature of the fold being formed, and rotates about said centre of curvature, remaining tangential to that centre throughout a folding operation. This surface bears against the sheet and forms a bend in the sheet in accordance with curve followed by the fold bar. The final curve formed in the sheet is strongly dependent on the springback in the metal being formed.

[0003] Existing tangent benders or folders generally provide for the moving fold bar to over bend the material in order that when spring back occurs the bend is approximately the angle required. As metals have varying tensile yield stress according to the batch and the age of the sheet this spring back will vary necessitating manual adjustment of the stop position to ensure accurate bend angle. Often one or more sheets from each batch will be scrapped in the process of achieving the correct bend angle and the achievable tolerance is often less than desired for the end product.

SUMMARY OF THE INVENTION

[0004] It is an object of the present invention to provide a sheet metal folder and/or a control system for a sheet metal folder and/or methods of controlling a sheet metal folder, which will at least go some way towards overcoming the above disadvantages or at least provide the industry with a useful choice.

[0005] In a first aspect the invention consists in a sheet metal folder including a movable fold bar, actuation means to move said moveable fold bar, sheet position monitoring means which monitor the position of the folded portion of a sheet, and control means which are adapted to perform, during folding, the steps of:

moving said fold bar to a first fold position,
retreating said fold bar to a position in which said sheet is no longer contacted by said fold bar,
registering the current position of said sheet,
calculating a second fold position wing the difference between said first fold position of said fold bar and said registered position, and
moving said fold bar to said second fold position.

[0006] In a further aspect the invention consists in a control system for an existing tangent folder comprising:

sheet position monitoring means which monitor the position of the folded portion of a sheet,
and an actuator control system programmed to, during folding, perform the steps of:
moving the fold bar to a first fold position,
retreating said fold bar at least until said sheet no longer contacts the face of the said fold bar,
registering the current position of said sheet,
calculating a second fold position using the difference between said first fold position and said registered position, and
moving said fold bar to said second fold position.

[0007] In a still further aspect the invention consists in a method of operating a tangent folder comprising the steps of:

moving the fold bar to a first fold position,
retreating said fold bar at least until a sheet no longer contacts the face of the said fold bar,
registering the current position of said sheet,
calculating a second fold position using the difference between said first fold position and said registered position, and
moving said fold bar to said second fold position.

[0008] To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Figure 1 shows a sheet metal folder of a tangential folder type with a sheet clamped in position in the folder, the movable fold bar has not yet rotated and no bend has been generated,
Figure 2 shows the folder of Figure 1 with the moving fold bar rotated to a first position where a minimal level of spring back has been compensated for,
Figure 3 shows the folder of Figure 2 where the fold bar has retreated from the first position, and the sheet has sprung back and continues to remain in contact with the fold bar at this position,
Figure 4 shows the folder of Figure 3 where the fold bar has continued to retreat, spring back is complete and a small gap has now been generated between the fold bar and the sheet,
Figure 5 shows the folder of Figure 4 with the fold

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bar rotated into a second fold position at a greater angle than the first fold position that has been calculated so that it may produce a correct final fold,

Figure 6 shows the folder of Figure 5 where the fold bar has retreated from the second fold position to a position where the sheet is now fully relaxed but the moving fold bar has not yet lost contact,

Figure 7 shows the folder of Figure 6 where the fold bar has continued to retreat and has flow lost contact with the sheet,

Figure 8 shows the folder of Figure 7 wherein the fold bar has retreated completely to its final position ready for the sheet to exit the folder,

Figure 9 is a diagram showing the fold and spring-back angles of an example folding operation, and

Figure 10 is a cross sectional end elevation of a tangential folder of which Figures 1-8 demonstrate part thereof.

DETAILED DESCRIPTION

[0010] With reference to the drawings, the present invention is applicable to a wide range of existing sheet metal folder types, including tangential folders such as that depicted in Figure 10. Tangential folders are particularly useful in applications involving a precoated metal sheet and for forming large radius bends. The present invention may require modification of conventional folders to incorporate a controlled drive having a variable final position, for example by providing actuation through one of the many types of available linear actuators. Furthermore some form of positional feedback is required during the folding process and in this regard it is preferred that the actuator be the type capable of providing positional information to its controller. A linear actuator such as a Parker ET Series electric cylinder or similar is appropriate. In addition a sensor capable of detecting when the metal sheet no longer contacts the fold face of the fold bar is required. This sensor may comprise a light sensor, or alternatively a capacitor sensor of known type.

[0011] Referring to Figure 10 a tangential folder of a conventional form is shown including a moving fold bar 102, a clamp 103 and a fixed fold bar 104. Clearly the fixed fold bar 104 and clamp 103 may be easily interchanged as regards which of the two components moves relative to the other in grasping and holding of a sheet. In the form illustrated in Figure 10 the lower member 103 moves to clamp against the upper member 104 to retain the sheet, the lower member 103 being supported by a linear moving carrying arrangement 105 guided by a track 106 and actuated by an actuator 107. The upper clamping member 104 is supported on a beam 108.

[0012] The moving fold bar 102 is carried by a carriage 109 supported at each end by a substantially circular hub 110 (with a large section removed to allow sheet ingress and egress with the fold bar carriage 109 in a start/finish position) which rotates within a complementary circular bush 111. Movement of the fold bar carriage 109 is actuated by actuator 112. The particulars of arrangements form no part of the present invention.

[0013] In Figures 1 - 8 a tangential folder of conventional type is shown with a moving fold bar 2, a clamp 3 in a fixed fold bar 4. The tangential folder has been modified to include a sensor or microswitch 5 in the moving fold bar 2. In the figures a sheet 1 is shown clamped between to clamp 3 and the fixed fold bar 4.

[0014] In the present invention a controller controlling the movement of the folder makes an initial fold to a first fold position, detects the amount of spring back and calculates a second fold position based on the detected spring back which may provide a correct final relaxed position for the sheet. It then performs a second fold to this second fold position and, preferably once more checks the amount of spring back and ensures that the final relaxed position of the sheet is within a tolerable limit to that required. At least in the first sheet of each batch the folder selects an initial fold position which is guaranteed to be a lesser angle than that required to ensure that no over bend occurs (which would be irreversible) Subsequent sheets in the batch can be processed based on the second fold position from the first sheet as their first fold position and can usually be folded in a single folding operation. In each case the amount of spring back is monitored to ensure that no under folding is occurring. Where, during folding of a batch of sheets, a final fold angle is detected that is outside or is close to a standard tolerance range, the folder control system preferably re runs the calibration steps as required.

[0015] Referring now to Figures 1 to 8 they show a folding sequence of a tangential folder controlled according to the present invention. The sequence shows a folding operation as it may be performed on the first sheet of a batch. The sheet 1 is clamped between a clamp 3 and the stationary fold bar 4 as shown in Figure 1. The fold bar 2 is actuated to a first fold position as indicated by the position in Figure 2. Being a tangential folder this movement is made in the manner indicated by the locus 6, arrow 8 and centre 7. This first position is set to ensure that for any material that is intended to be handled by the folder spring back of the sheet will leave the sheet short of the intended final position (see Figure 4). For material of unknown properties the control system may be configured to set this first position as being the final intended position for the sheet, so that no risk of over folding or over bending is possible.

[0016] Referring to Figure 3 the moving fold bar is caused to retreat from its first position in the direction indicated by arrow 9 and the sheet 1, in spring back mode, follows, remaining in contact with the folding face 10 of the folding bar 2 until it reaches it's relaxed position. With the sheet in the relaxed position, as depicted in Figure 4, with the fold bar 2 still retreating as indicated

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by arrow 9 the face 10 comes out of contact with the sheet 1 and this condition is detected by the sensor or microswitch 5. At this time the control system requests positional information from the linear actuator controlling the position of the fold bar 2. This positional information provides an indication of the overall spring back angle for the initial fold. From this spring back angle the control system calculates a second fold position for the fold bar 2 for a second fold operation, which it is expected will leave the sheet 1 in the desired final position (within tolerance) in a relaxed mode after spring back. The fold bar 2 is then actuated to this second position as indicated by arrow 11 in Figure 5.

[0017] The fold bar 2 is subsequently retreated from the second position as indicated by arrow 12 in Figure 6 with spring back of the sheet material retaining the material in contact with the face 10 of the fold bar 2 until it reaches its relaxed position (approximately the position shown in Figure 6). As in the earlier retreating movement the motion is continued in the direction of arrow 12 until the sensor or microswitch 5 detects that the sheet 1 is no longer in contact with the face 10 of the fold bar 2. Again the controller requests positional information from the linear actuator and from this calculates the final reined position of the folded sheet 1. Assuming that this position is in the required tolerances the fold bar 2 is retreated completely to its initial position as indicated by arrow 13 in Figure 8. If instead, further bending of the sheet is still required, then a further iteration of the calculation and bending can be instituted. However, with the algorithm as set out below it has been found that in general, a satisfactory fold is achieved wit the two iterations described fully above.

[0018] Given that a degree of knowledge is now available to the control system subsequent sheets of the same batch may be folded based on a calculated first position which brings the sheet 1 much closer to the final reined position that it intended. Generally this first position for subsequent sheets will be equivalent to the second position used on the initial sheet of a batch.

[0019] Referring now to Figure 9, an example of a typical sequence of folding angles is shown diagrammatically.

FIRST FOLD

[0020] The first fold must guarantee an underfold for all materials. Therefore the maximum first fold position (x_1) will be the fold that could possibly give final fold position (N). At completion of the fold and retreat of the fold bar, the final position (y_1) and the spring back angle (z_1) are determined.

[0021] The first springback value (z_1) is stored in memory to be referred to in the next folding operation. If the value of z_1 is considerably deviant from the previous fold operation, this indicates that a change in material may have occurred. This information may need to be considered in the second fold position calculation i.e recalculate a new p value on the assumption no history is available (see below).

SECOND FOLD

[0022] The amount of overbond required on the second fold will be related to the amount of springback measured from the first fold.

The second fold position is calculated as

$$x_2 = y_1 + p.z_1$$

where p is a "constant" depending on the material and is initially unknown but which is calculated depending on the folding history of the material switch. Note that with a value p=1, the second fold position (x_2) = first fold position (x_1) and hence p will always be greater than 1.

[0023] On the very first fold when there is no history available, an initial p value is determined on the basis that additional overfolding will give a springback at approximately 0.8 times that just experienced (an amount which compensates for work hardening and has been derived from experiment).

Therefore for the second fold position

$$x_2 = N + 0.8\, z_1$$

Hence for the initial p value (no history):

$$= 0.8 + \frac{(N-y_1)}{z_1}$$

which gives p = 1.8 if the most conservative fold sequence is chosen with $x_1 = N$.

[0024] Once a fold history is established, p will be recalculated after second fold based on the last two folds as follows:

$$= 1 + \frac{(x_2 - x_1).(N-y_1)}{(y_2 - y_1).z}$$

[0025] Thus as further sheets are processed, should calibration or repeat of the multiple fold process be required, a better indication for use in calculating the second fold position is available.

[0026] As can be seen in the above description and from the drawings, the invention provides a folder which gives accurate folding based on a multiple step process of calibration and can therefore cope with differing materials and differing batches. This is particularly important in modem manufacturing processes where a folder may be folding sheet for use in a variety of products, although, often nominally of the same gauge, will frequently be sourced from different batches (for reasons such as colour, surface finish etc). It has been

found that the invention provides excellent accuracy for such folding particularly in folding where large cower radiuses are required.

[0027] The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

Claims

1. A sheet metal folder including a movable fold bar (2), actuation means to move said moveable fold bar (2), sheet position monitoring means which monitor the position of the folded portion of a sheet (1), and control means which are adapted to perform, during folding, the steps of:

   moving said fold bar (2) to a first fold position,
   retreating said fold bar (2) to a position in which said sheet (1) is no longer contacted by said fold bar (2),
   registering the current position of said sheet (1),
   calculating a second fold position using the difference between said first fold position of said fold bar (2) and said registered position, and
   moving said fold bar (2) to said second fold position.

2. A sheet metal folder as claimed in claim 1 wherein said sheet position monitoring means comprises indication means to indicate the position of said moveable fold bar and detection means (5) to detect whether said sheet (1) resides against a surface (10) of said moveable fold bar (2), and said current position of said sheet (1) is registered by registering the position of said fold bar (2) immediately said sheet (1) no longer resides against said fold bar.

3. A sheet metal folder as claimed in either claim 1 or claim 2 wherein said surface (10) of said moveable fold bar (2) against which said sheet (1) resides faces the centre of curvature (7) of the fold being formed, and rotates about said centre of curvature (7), remaining tangential thereto throughout said folding operation.

4. A sheet metal folder as claimed in any one of claims 1 to 3 wherein said second fold position is calculated according to an algorithm wherein said second fold position is calculated as said first springback position with the addition of an initially set proportion of the amount of said springback, said proportion being greater than 1.

5. A sheet metal folder as claimed in claim 4 wherein a further folding operation is performed if said sheet is still not sufficiently folded after said second folding operation, and said proportion added is based on the springback observed during the two previous fold operations.

6. A sheet metal folder as claimed in any one of claims 1 to 5 wherein for each subsequent sheet of a batch to be folded said folder is actuated to a first position that is equal to a final fold position necessary for the previous sheet.

7. A sheet metal folder as claimed in claim 6 wherein said folder continues to monitor said springback position of the sheet and if said position is close to a tolerance, either greater or lesser than the ideal position, said folder adjusts said fold position and/or repeats the calibration process for the next sheet.

8. A control system for an existing tangent folder comprising:

   sheet position monitoring means which monitor the position of the folded portion of a sheet (1), and an actuator control system programmed to, during folding, perform the steps of:
   moving the fold bar (2) to a first fold position,
   retreating said fold bar (2) at least until said sheet no longer contacts the face (10) of the said fold bar,
   registering the current position of said sheet (1),
   calculating a second fold position using the difference between said first fold position and said registered position, and
   moving said fold bar (2) to said second fold position.

9. A control system as claimed in claim 8 wherein said sheet position monitoring means comprises indication means to indicate the position of said moveable fold bar and detection means (5) to detect whether said sheet (1) resides against a surface (10) of said moveable fold bar (2), and said current position of said sheet (1) is registered by registering the position of said fold bar (2) immediately said sheet (1) no longer resides against said fold bar (2).

10. A control system as claimed in either claim 8 or claim 9 wherein said second fold position is calculated according to an algorithm wherein said second fold position is calculated as said first springback position with the addition of an initially set proportion of the amount of said springback, said proportion being greater than 1.

11. A control system as claimed in claim 10 wherein a further folding operation is performed if said sheet

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is still not sufficiently folded after said second folding operation, and said proportion added is based on the springback observed during the two previous fold operations.

12. A control system as claimed in any one of claims 8 to 12 wherein for each subsequent sheet of a batch to be folded said folder is actuated to a first position that is equal to a final fold position necessary for the previous sheet.

13. A control system as claimed in claim 12 wherein said folder continues to monitor said springback position of the sheet and where said position is close to a tolerance, either greater or lesser than the ideal position, said folder adjusts said fold position and/or follows repeats the calibration process for the next sheet.

14. A method of operating a tangent folder comprising the steps of:

moving the fold bar (2) to a first fold position,
retreating said fold bar (2) at least until a sheet (1) no longer contacts the face (10) of the said fold bar (2),
registering the current position of said sheet (1),
calculating a second fold position using the difference between said first fold position and said registered position, and
moving said fold bar (2) to said second fold position.

15. A method of operating a tangent folder as claimed in claim 14 including the continuing step of detecting whether the said sheet (1) resides against a surface (10) of said fold bar (2), and wherein said step of retreating said fold bar comprises retreating said fold bar until said detecting indicates that said sheet (1) no longer resides against said surface (10) of said fold bar (2), and said step of registering the current position of said sheet comprises registering the current position of said fold bar (2) immediately said detecting indicates that said sheet (1) no longer contacts said face (10) of said fold bar (2).

16. A method of operating a folder as claimed in either claim 14 or claim 15 wherein said second fold position is calculated according to an algorithm wherein said second fold position is calculated as said first springback position with the addition of an initially set proportion of the amount of said springback, said proportion being greater than 1.

17. A method of operating a folder as claimed in claim 16 wherein a further folding operation is performed if said sheet is still not sufficiently folded after said second folding operation, and said proportion added is based on the springback observed during the two previous fold operations.

18. A method of operating a folder as claimed in any one of claims 14 to 17wherein for each subsequent sheet of a batch to be folded said folder is actuated to a first position that is equal to the final fold position necessary for the previous sheet.

19. A method of operating a folder as claimed in claim 18 wherein said folder continues to monitor said springback position of the sheet and when said position is close to a tolerance, either greater or lesser than the ideal position, said folder adjusts said fold position and/or repeats the calibration process for the next sheet.

FIG. 1

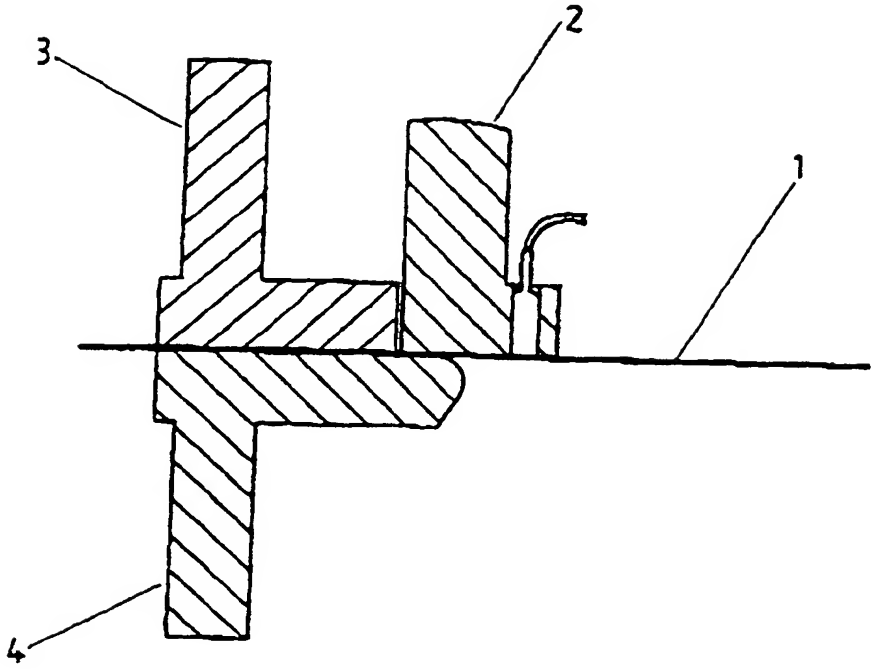

FIG. 2

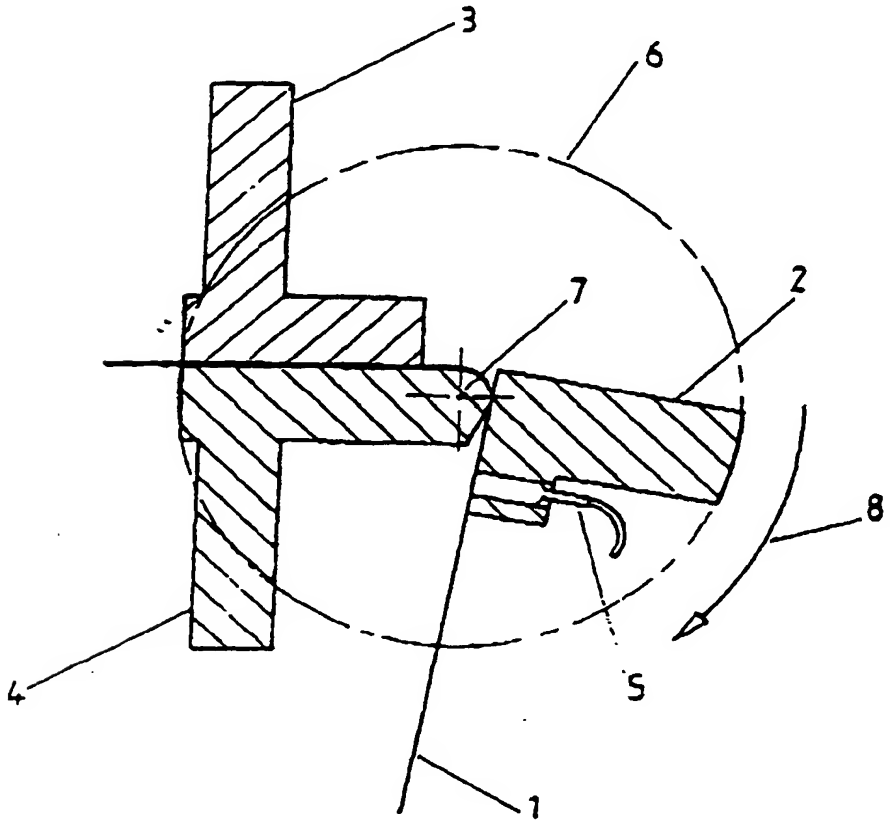

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FIG. 3

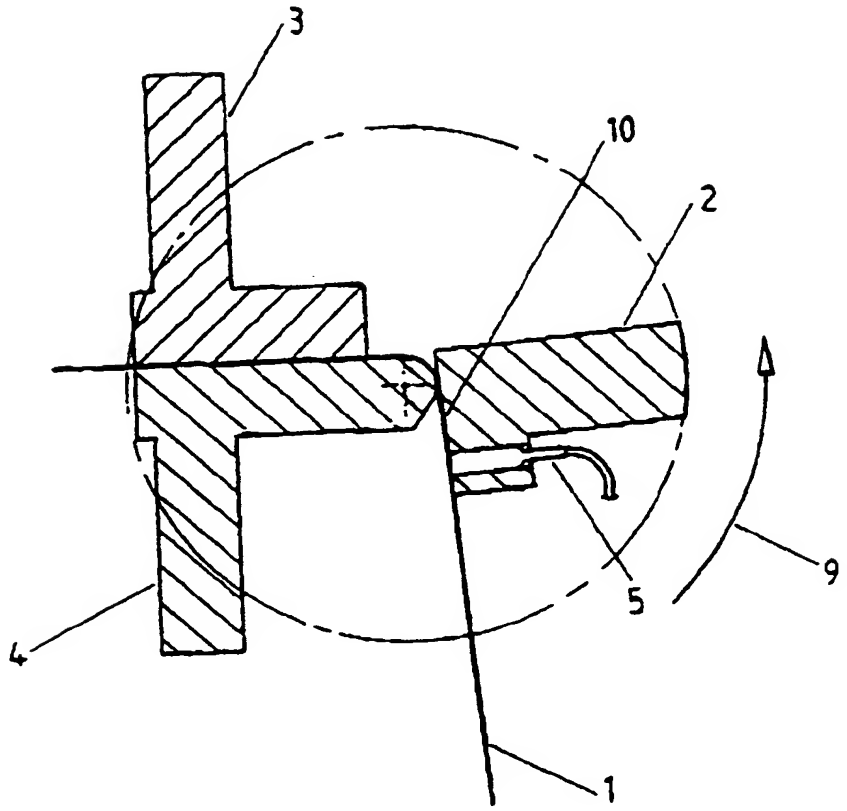


FIG. 4

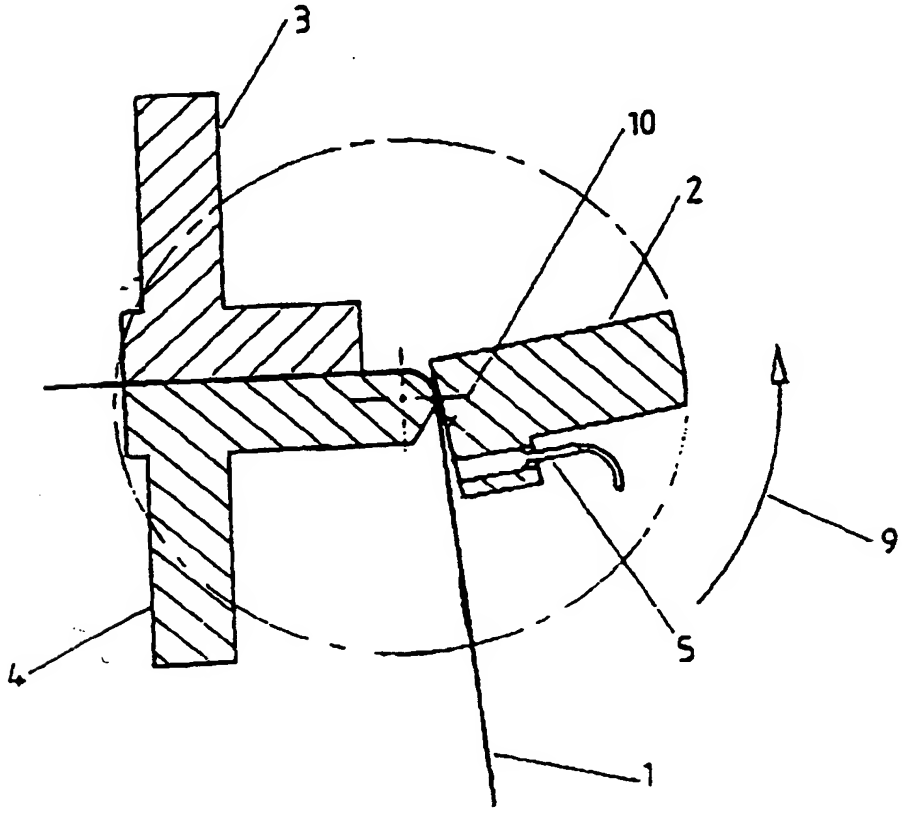


FIG. 5

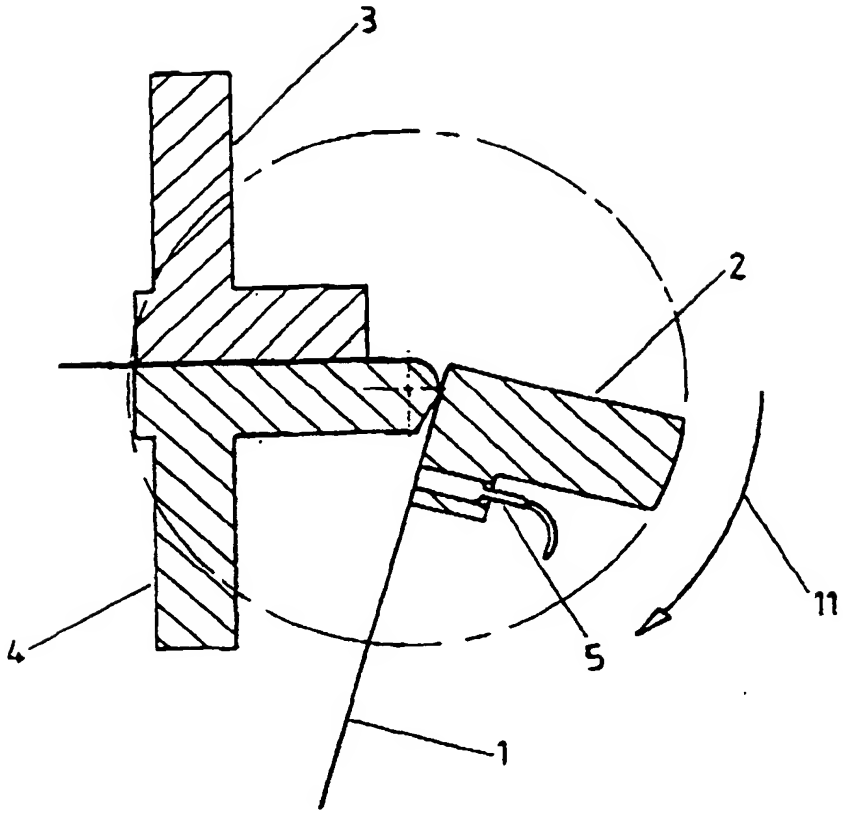


FIG. 6

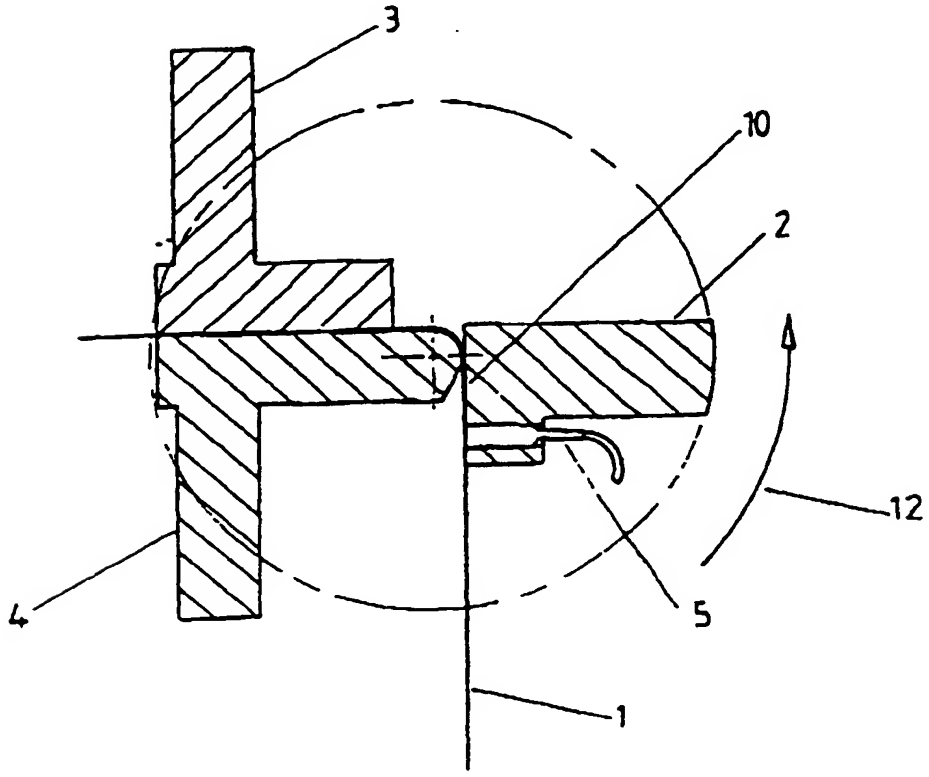


FIG. 7

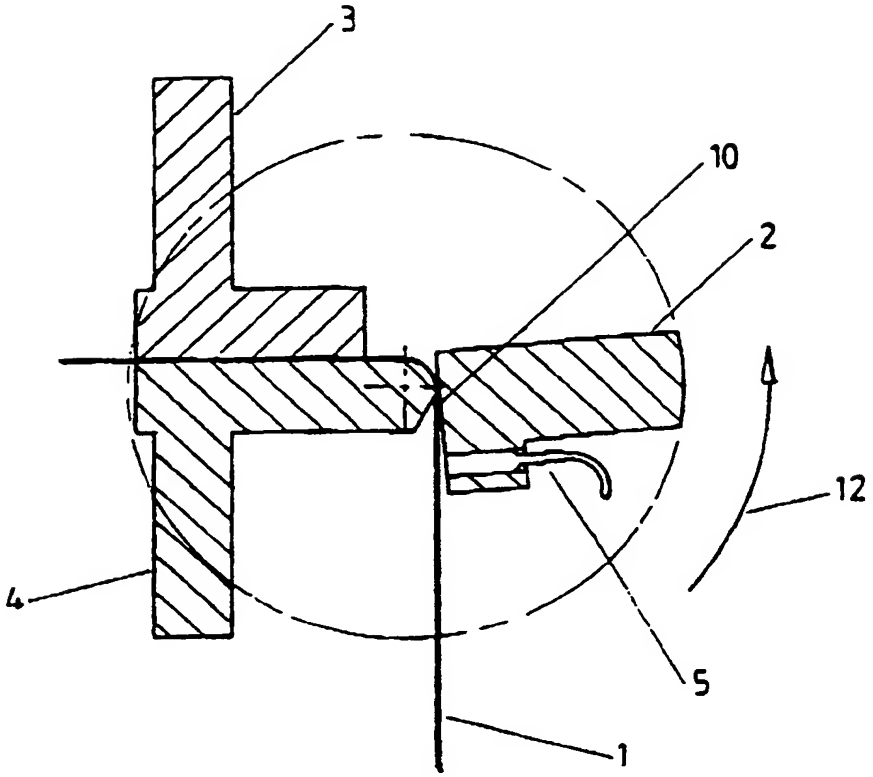
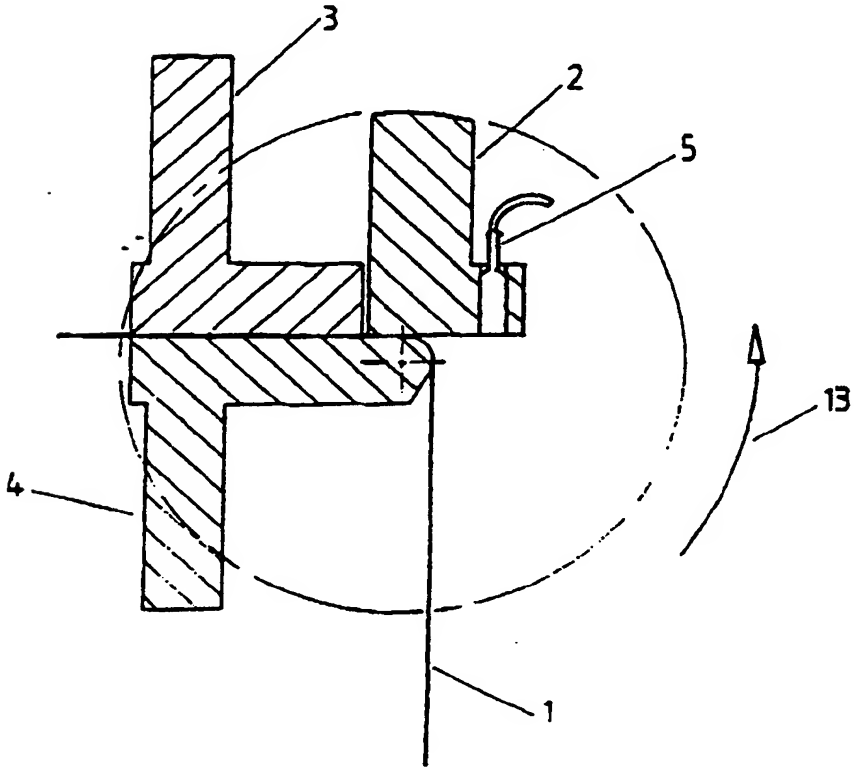


FIG. 8



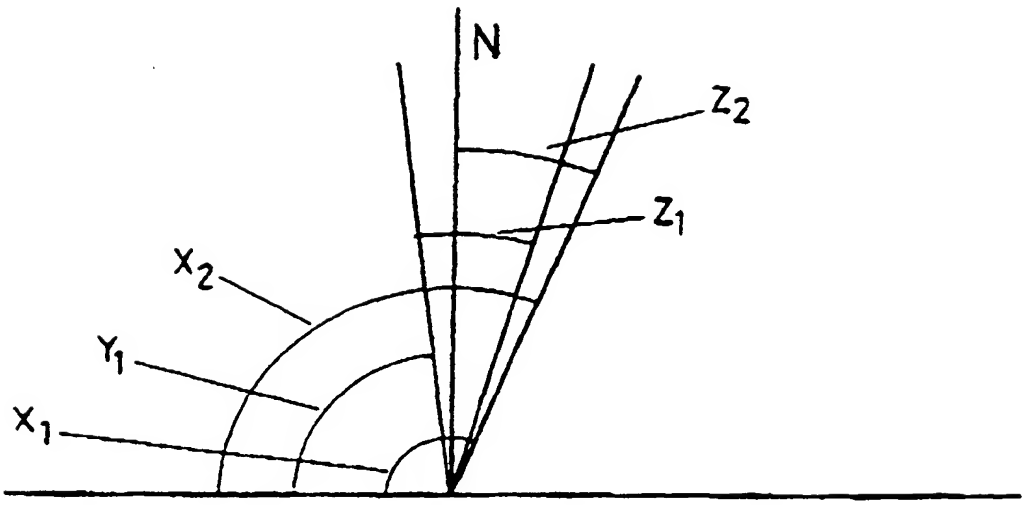


FIG. 9

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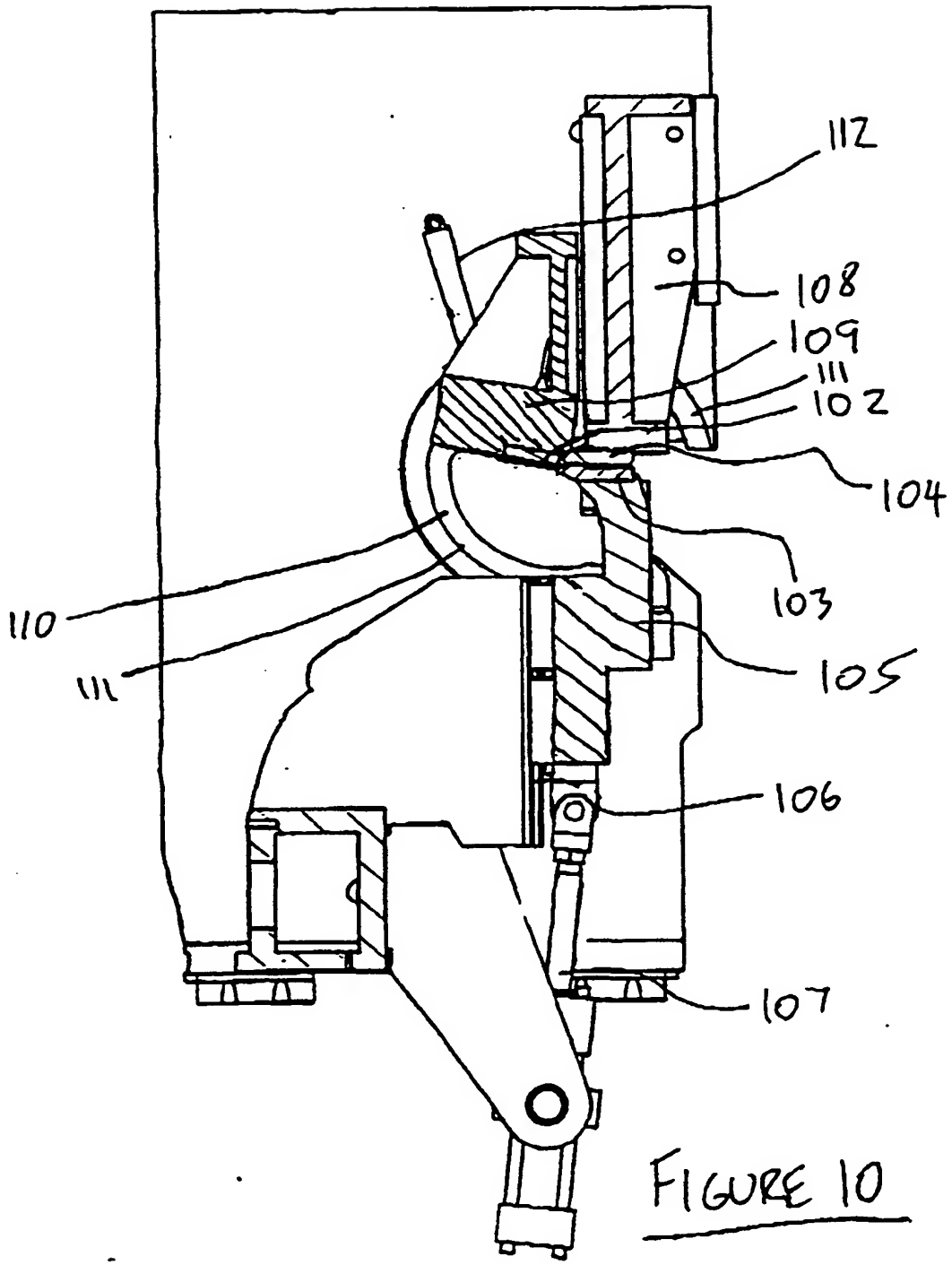

FIGURE 10

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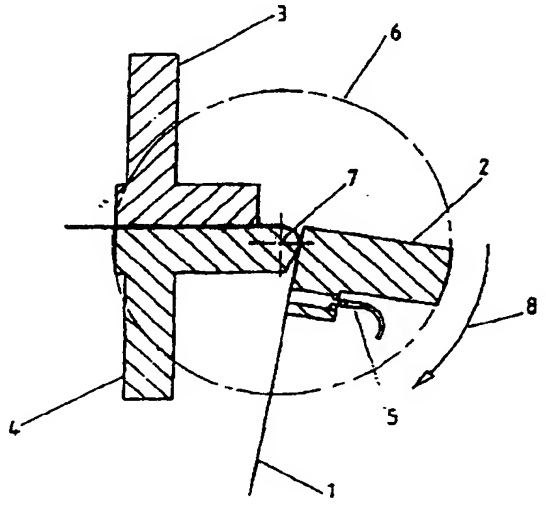
FIG. 2



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EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 10 6272

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	JP 06 163317 A (HITACHI) 10 June 1994 (1994-06-10) * abstract; figures 1,3 *	1-19	B21D5/04
X	US 5 007 264 A (HAACK) 16 April 1991 (1991-04-16) * column 2, line 33-52; figure 2 *	1-19	
X	DE 27 04 399 A (FASTI WERK CARL AUG. FASTENRATH) 10 August 1978 (1978-08-10) * page 9, last paragraph * * page 10, paragraph 1 *	1-19	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			B21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	11 September 2001	Ash, R

CATEGORY OF CITED DOCUMENTS

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